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INFORMATION FOR VISITORS

at the

Red Plains Conservation Experiment Station
Guthrie, Oklahoma

and the

Wheatland Conservation Experiment Station
Cherokee, Oklahoma

By
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and
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OKLAHOMA AGRICULTURAL EXPERIMENT STATION
Oklahoma A. and M. College, Stillwater

in cooperation with

RESEARCH DIVISION, SOIL CONSERVATION SERVICE
United States Department of Agriculture

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By HARLEY A. DANIEL, HARRY M. ELWELL, and MAURICE B. COX*

Methods of controlling erosion, and of bringing eroded and unused land into production, have been studied over the past 18 years at the Red Plains Conservation Experiment Station near Guthrie, Oklahoma. Since 1939, similar studies for the northwestern Oklahoma wheat area have been made at the Wheatland Conservation Experiment Station near Cherokee. These stations are conducted cooperatively by the Oklahoma Agricultural Experiment Station and the Research Division of the U. S. Soil Conservation Service.

The research findings at these stations are fundamental facts which help provide a basis for planning a coordinated soil conservation program for individual farms and ranches. It cannot be expected that every conservation practice proved sound by research will apply to every farm. Methods of conserving and improving a particular farm or ranch will depend upon the types of land included.

The Soil Conservation Service (9)** has set up eight capability classes of land, divided into three broad uses:

(a) Land suitable for continuous cultivation.
(b) Land adapted only for permanent vegetation such as grass or timber.
(c) Land from which plants cannot be harvested. It is ordinarily extremely rough, sandy, wet or arid, and is best adapted for wild life production.

Land within these use-groups differs in soil characteristics, slope, and degree of erosion. It also differs in crop-producing power and in the kinds of crops and livestock it is best suited to produce. To get the most from each piece of land year after year, it must be used correctly (15). Before it can be used correctly, the land must be classified as to erosion hazard, the kind of crops it is suited to produce, and the soil conservation and fertility maintenance practices needed to keep it producing. Only then can an individual soil conservation farm plan be worked out to include: (a) Sound land use; (b) the right combination of conservation practices; (c) the maintenance

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** Bold figures in parentheses refer to "Literature Cited," page 30.

and improvement of soil fertility; and (d) economically sound farm management.

The research at the Red Plains and Wheatland Stations is directed at finding the best ways of handling certain types of land to insure its proper use. This bulletin was prepared to aid visitors to these stations by summarizing research up to date. Such research findings at these and other experiment stations are clarifying the relationship of soil, plant, animal and people, and are providing the basis for a permanent agriculture based on sound land use, conservation, fertility improvement, and wise management.

METHODS OF CONSERVING LAND SUITABLE FOR CULTIVATION

Grass and other thick-growing vegetation controls erosion and rebuilds soil (Figure 1). But some land must also be used for cultivated crops. These cultivated fields can be protected from erosion and the fertility maintained by continuously following a sound program of soil use and management. A continuous individual plan for each farm will become more important in determining crop and food production in coming years. Practices which may fit into such plans are being tested at both Guthrie and Cherokee; the results of these tests are discussed in the following paragraphs.

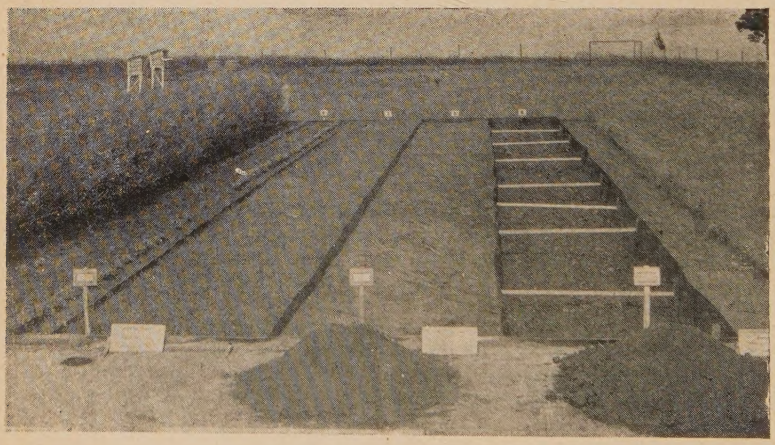

Fig. 1. Relation of Plant Cover to Soil Erosion.

The piles of soil in front of each plot represent the average annual amount of erosion since 1930 at the Red Plains Conservation Experiment Station. The tons of soil per acre removed in the runoff water from these plots was (left to right): Bermuda grass, 0.020; bare hard fallow, 16.323; and continuous cotton on eroded soil (10 inches removed), 28.127.

Fig. 2. Basin Lister Dams Broke Where Furrows Ran Up and Down Hill.

High intensity rains wash out dams in basin listed furrows which run up and down the slope. Water loss in runoff was higher from these plots than from plowed land (Table I). But both listing and basin listing greatly reduced runoff water losses when the lister followed the contour.

Moisture Conservation and Erosion Control

Terraces properly constructed and maintained are recognized as the basic mechanical method of preventing erosion on arable land (4). In semi-arid regions, the primary function of terraces is to conserve moisture. In humid regions it is to shorten length of slope over which water must pass, and thereby reduce velocity of runoff from fields. Terraces are also expected to meet the requirements of the soils and slopes of the land on which they are placed. Systems of design must therefore be worked out to meet the particular conditions of the field to be protected.

The effectiveness of conserving moisture for wheat production is being studied on the Wheatland Conservation Experiment Station at Cherokee.*

Contour Cultivation and Terraces

The effect of contour cultivation and terraces on the conservation of runoff water and crop yields on deep soil is given in Table I. Where all cultivation was conducted with the slope, the lowest amount of runoff was from the mulch plots and the highest from the listed plots. On plots basin listed with the slope, the dams in the furrows often broke during heavy rains (Figure 2), and this may account for the runoff being higher from

* Different methods of continuous tillage on terraced and unterraced land are studied on 48 plots, and rotation of tillage methods is studied on nine small natural watersheds. All plots and watershed treatments are in triplicate. Information on the methods used in these studies is available upon request from the Project Supervisor, Red Plains Conservation Experiment Station, Guthrie, Oklahoma.

TABLE I. Effect of Tillage Method, Contour Cultivation and Terraces on Runoff Water from Deep, Permeable Soil; Cherokee, Oklahoma (1).

Method of tillage	Percentage of rainfall lost in runoff			Percentage of runoff saved by:	
	Cultivated with slope	Cultivated on contour	Terraced and cultivated on contour 2	Contouring	Terracing and contouring
Stubble mulch	12.0	11.1	6.9	7.5	42.5
Plowed	12.8	11.0	7.4	14.0	42.2
Listed	14.4	9.7	8.5	32.6	41.0
Basin listed	13.8	8.1	7.4	41.3	46.4
Average	13.2	10.0	7.5	24.2	43.2

1 Results for crop year (July 1 to June 30). Six-year average 1942-47. Average annual rainfall 25.6 inches.
2 Short level terraces with one end open.

these plots than from the plowed land. But both listing and basin listing greatly reduced runoff water losses when listing followed the contour. In fact, during the past six years the amount of runoff was reduced 24.2 percent when the tillage followed the contour. This is an average of the four types of tillage.

Although contour cultivation gives an outstanding saving of moisture, contour cultivation alone is not enough on land slopes over 1.5 percent. On these steeper slopes, a combination of terraces and contour cultivation is needed. The combination at Cherokee conserved an average of 43.2 percent more water than unterraced land cultivated with the slope. The amount of soil lost was not recorded at Cherokee, but at Guthrie terraces also greatly reduced soil losses and prevented severe erosion (3, 4).

The first and second year after the terraces were built at Cherokee the yield of wheat on the terraced and contour cultivated plots was less than on those cultivated with the slope (Table II). But, beginning with the third year (apparently after nature had time to adjust soil conditions in the disturbed portion of the ridges and channel), the yields have been higher on the terraced and contour cultivated plots. Although the rainfall for the third crop year (1945) was well distributed and 8.6 inches above normal, terraces and contour cultivation increased the yield an average of 1.3 bushels per acre. With the exception of the first year, contour cultivation alone also increased crop yields.

Vegetated Waterways

Before terraces are built, provision must be made to dispose of the runoff water. Broad, naturally vegetated drainage ways are best for this purpose (2). When they are not available, channels must be made (Figure 3). Various kinds of plants for lining these channels are being tested at Cherokee. The results show that individual species respond differently under different soil conditions (Table III). Sod-forming grasses are the best plants for lining water channels, as shown by tests at Guthrie and at the Outdoor Hydraulic Laboratory near Stillwater (2, 3). Buffalo grass has also made a good cover for channels on the Cherokee station. Bunch grasses and legumes do not provide as dense a soil cover as the sod grasses; but at Cherokee,

TABLE II. Effect of Contour Cultivation and Terraces on Wheat Yields at Cherokee, Oklahoma (1).

Year	Wheat yields (Bushels per acre)			Difference in yield (bushels per acre) due to:		Precipitation (3)	
	Cultivated with slope	Cultivated on contour	Terraced and cultivated on contour2	Cultivating on contour	Terracing and cultivating on contour	Total annual (inches)	Departure from average (inches)
1942	16.0	15.5	14.1	-0.5	-1.9	30.0	+4.4
1943	9.2	9.9	8.0	0.7	-1.2	20.3	-5.6
1944	17.7	19.2	19.4	1.5	1.7	20.4	-5.5
1945	23.2	24.6	24.5	1.4	1.3	34.3	+8.6
1946	21.0	24.0	23.8	3.0	2.8	23.7	-2.1
1947 (4)	18.8	19.5	20.0	0.7	1.2	24.6	-1.2
Aver.	17.6	18.8	18.3	1.1	0.7	25.6	-0.3

1 Data compiled from averages of stubble mulch, plowed, listed and basin listed plots.
2 Short level terraces one end open.
3 Based on Weather Bureau record in Cherokee, Oklahoma, since 1915.
4 The rainfall at seeding time was below the average, but above the average during the spring growing season.

where the soil is deep and fertile, weeping love grass, switch grass and mixtures of these and other grasses are giving adequate protection for outlet channels on land slopes of two to three percent. Alfalfa is providing a satisfactory protective cover in some channels on the flatter slopes at this station.

These studies, field observations, and hydraulic data show that vegetation in water channels should be frequently mowed or systematically grazed for best results. This promotes good tillering and reduces excessive turbulence in the flow of water, which aids in preventing irregular silt deposits.

The success of a vegetated waterway depends upon proper design of channel, condition of soil, selection and establishment of plants, and method of maintenance.

Tillage Methods for Wheat

The highest average yield of wheat to date from the continuous tillage tests on the station at Cherokee has been produced on the plowed land. Yields have been lowest on the stubble mulch plots (Table IV). The average yields on the listed and basin listed land have been the same, and they are only slightly less than on the plowed land. The mulched plots have consistently contained a heavy growth of cheat and weeds, and the wheat plants have been attacked by an infestation of foot rot each season beginning with 1944. During 1943 some straw worm damage was also observed on the mulched plots.

The highest average yield to date on the watersheds has been produced on the one-way plowed land and the lowest on the stubble mulch areas (Table V). The annual water loss in runoff from the watersheds was the highest from the one-way plowed land. Where the tillage methods were rotated, weeds, foot rot, etc., have not been a serious problem.

Therefore it appears that in order to take advantage of moisture conditions a flexible system of tillage may be used (5, 6). When soil moisture

Fig. 3. Vegetated Waterways Carry Water from Terraces Safely.

A broad, flat water channel protected by vegetation on the Wheatland Conservation Experiment Station. This kind of channel is satisfactorily disposing of runoff water from terraced land. Plants used for vegetating water channels are listed in Table III.

TABLE III. Plants for Vegetating Broad, Flat Water Channels (1).

Grasses and legumes (2)	Conditions for Best Use		
	Fertility	Slope Percent (3)	Growing Season (4)
Sod Type (5)			
Bermuda	medium	15	1
Buffalo	high	8	2
Vine Mesquite	high	5	2 to 3
Bunch Type (6)			
Weeping Lovegrass (5, 6)	medium	5	1
Blue Grama	medium	5	2 to 3
Side-oats Grama	medium	5	2 to 3
Yellow Bluestem	medium	5	2 to 3
Mixtures (6)			
Buffalo, Blue and Side-oats Grama	medium	7	2
Switch, Weeping Lovegrass, Buffalo and Blue Grama	medium	5	2 to 3
Legume (6)			
Alfalfa	high	2	1

1 These plants are being tested in water channels on the Conservation Experiment Stations at Guthrie and Cherokee.
2 Maximum silting moderate for Bermuda grass, all others slight.
3 Maximum slope percent based on reports by Cox and Palmer (2).
4 Number of seasons needed under good growing conditions before water can be turned in channel.
5 Soil condition (12) permeable to slowly permeable.
6 Soil condition (12) permeable.

conditions are favorable following harvest, the crop residue may be worked into the top-soil. But if dry weather prevails, immediate one-way disking or other surface tillage appears to be justified in the area represented by the station at Cherokee.

For the higher, more arid section of Oklahoma, it may be necessary to introduce sorghum or fallow into the cropping system for controlling wind erosion. Under such conditions, methods of soil and water conservation, fertility maintenance and crop production must be developed in harmony with natural conditions. But Daniel (6) has suggested a combination of tillage and crop successions which is flexible enough for the extreme annual variations encountered in the Southern Great Plains.

Water Spreading

Another study under way at Cherokee involves the conservation value of collecting runoff water from higher sloping land and spreading it on lower, more level, deep permeable soil. This experiment was started in the summer of 1944 by systematically designing and constructing level terraces on intervals of one foot in a "syrup pan" (spread and spill) type of arrangement. This forces the water to completely cross the field in the interval between each terrace (Figure 4). As the water moves slowly back and forth over such a large surface, much of the surplus is absorbed by the soil and retained for plant use.

The area occupied by the water-spreading terraces at Cherokee has been completely flooded thirteen times since the experiment was started. Six of these floods occurred in the spring of 1947. However, the water drained off

TABLE IV. Effect of Different Methods of Continuous Tillage on Yields of Wheat; Cherokee, Oklahoma.

Method of tillage	Yield of wheat per acre (1)	
	Grain (Bushels)	Straw (Tons)
Plowed	19.9	1.52
Basin listed	19.2	1.47
Listed	19.0	1.46
Stubble mulch	15.0	1.21

1 Six years 1942-47. Precipitation average 25.6 inches.

TABLE V. Effect of Different Methods of Rotated Tillage on Wheat Yields and Runoff Water; Cherokee, Oklahoma (1).

Method of tillage (2)	Yield of wheat per acre (3)		Percent runoff (4)
	Grain (Bushels)	Straw (Tons)	
One-way plowed	19.7	1.52	10.9
Basin listed	18.8	1.46	8.2
Stubble mulch	17.8	1.32	9.3

1 For crop year (July 1 to June 30).
2 Cultivated on contour.
3 Average of six years 1942-47.
4 Average of five years 1943-47

Fig. 4. Water Spreading.

The conservation value of collecting runoff water from higher sloping land and spreading it on lower, more level, deep permeable soil is being studied at the Wheatland Conservation Experiment Station. The water spreading is done by systematically designed level terraces in "syrup pan" type of arrangement.

without noticeable damage to alfalfa. This method of spreading and conserving the excess water prevented it from collecting in a pond that formerly developed in the northwest corner of the station.

The "syrup pan" (spread and spill) terrace, therefore, may serve two very important purposes on the valuable wheat and alfalfa land typical of northwestern Oklahoma:

(a) In many places it has possibilities of providing the most desirable outlet for the excess runoff.

(b) On other areas it may also be used advantageously to prevent the excess water from accumulating in ponds and destroying the crops.

Crop Rotation

A crop rotation of cotton, wheat and sweet clover has reduced soil loss 76 percent and runoff water 33 percent annually as compared to continuous cotton during 18 years at the Guthrie station (Figure 5 and Table VI). Both the wheat and sweet clover greatly reduced erosion, but the amount of soil removed from the wheat plot was 5.9 times more than that from sweet clover. The native grass sod was broken out and this experiment started on virgin soil in 1929. The yield of seed cotton in the rotation the first and second five-year periods was less than that on the continuous area. But during the third period it was 58.5 percent higher, and in 1945-47 it increased an average of 174.7 percent. The yield of seed cotton on the continuous area the last five-year period was 96 pounds per acre less than in the first five-year period, whereas on the rotation plot it was 170 pounds more (Table VII).

The extent to which any crop rotation is effective in reducing soil and water losses is primarily dependent upon two factors: First, the proportion of close-growing vegetation in the rotation; and second, the length of time and season of the year that this close-growing vegetation occupies the land. Close-growing, cultivated plants that produce protective land cover during the critical soil loss periods are especially valuable in conserving soil and water (3).

Sixty percent of the annual precipitation at Guthrie was received during the months of April, May, June, August, and September. But an average

TABLE VI. Percentage of Reduction in Soil and Water Losses and Difference in Yield of Cotton from a Rotation of Cotton, Wheat, and Sweet Clover as Compared to That of Continuous Cotton; Guthrie, Oklahoma (1).

	1930-34	1935-39(2)	1940-44	1945-47	1930-47
Reduction in soil loss	76.8	80.1	80.3	69.4	76.0
Reduction in water loss	19.9	17.9	47.6	52.4	33.3
Gain or loss in cotton yield (3)	-9.5	-5.9	58.5	174.7	16.0

1 This experiment was started on virgin soil in 1929.
2 Beginning in 1940, all plots have received superphosphate at the rate of 250 pounds per acre every third year. The fertilizer was applied under sweet clover in the rotation.
3 Seed cotton.

TABLE VII. Effect of a Rotation of Cotton, Wheat and Sweet Clover on Yield of Seed Cotton; Guthrie, Oklahoma (1).

Five-year period	Years	Annual precipitation (inches)	Pounds of seed cotton per acre		
			Continuous	Rotation2	Gain or loss
1	1930-34	33.39	474	429	-45
2	1935-39	26.44	510	480	-30
3	1940-44(3)	32.41	378	599	221
	1945-47	30.10	133	365	232
Average	1930-47	30.89	412	478	66

1 Experiment was started on virgin soil.
2 Cotton in rotation of cotton, wheat and sweet clover. The average per acre yield of wheat was 10.2 bushels and that of sweet clover, 1.88 tons.
3 Beginning in 1940, all plots received superphosphate at the rate of 250 pounds per acre every third year. The fertilizer was applied under the sweet clover in the rotation.

TABLE VIII. Effect on Cotton Yields of Using Erosion-resisting Winter Cover Crops, Fertilized and Unfertilized; Badly Eroded Land, Guthrie, Oklahoma (1).

Cover crops	Fertilizer(2)	Yield (pounds per acre)	Increase in yield (pounds per acre)
None	None	221	---
Vetch	None	276	55
None	4-12-4	440	219
Vetch	0-12-4	437	216
Vetch	4-12-4	487	266
Sweet clover(3)	0-20-0	493	272

1 Average of 17 years results 1931-47.
2 Applied at a rate of 300 pounds per acre annually.
3 Superphosphate applied at a rate of 100 pounds per acre when sweet clover was seeded. This area has been in cotton seven times during this period.

Fig. 5. Crop Rotations Conserve Soil.

The piles of soil represent the average annual amount of erosion from the different crops in the rotation since 1930, at the Red Plains Conservation Experiment Station. Pile 1, on the left, was from continuous cotton. Piles 2, 3, and 4 were, respectively, from the crops of wheat, sweet clover and cotton in the rotation.

of 77 percent of the total runoff water was lost in this period. July rainfall is usually low (4). Therefore, thick-growing vegetation and other conservation measures are most useful during the spring and fall months.

Cover Crops and Fertilizers

Small grain and other winter cover crops, if properly managed, are most effective for erosion control at the time of year when most of the runoff occurs (3). In addition, winter cover crops increased the yield of seed cotton (Table VIII). The best results were obtained when these crops received an application of fertilizer. Such crops also provide excellent early pasture.

The production of wheat on the stubble mulch plots at the Cherokee Station (Table IV) has been much less than that from the plowed plots. Since mulches conserve moisture and control erosion, an effort was made to increase the growth of small grain and produce a better land cover by applying various amounts of ammonium nitrate annually. The first application was made in March 1945, and the results to date are given in Table IX. These results are quite variable. The data in general indicate that wheat and barley respond only slightly to the small amounts of commercial nitrogen fertilizer. The greatest results appear to be on the stubble mulch land.

Observations, together with analyses made by the Oklahoma Agricultural Experiment Station, show that wheat land soils are rapidly losing organic matter. Since organic matter is a valuable aid in erosion control and accumulates from vegetation, an effort was made to produce a more adequate land cover, and also grow more wheat, by the addition of phosphorous and nitrogen fertilizers and the growing of legumes. The data for the first two years (Table X) tend to show the importance of legumes and phosphorus fertilizers on the growth of wheat. The increase in the rtraw production eventually adds more organic matter and develops a better land cover. The plots receiving phosphorus made a more rapid growth in the spring at the time when erosion is more severe, and also matured earlier than the check plots.* The best results to date have been obtained from a combination of superphosphate

* An extensive test of fertilization of wheat is reported in Okla. Agri. Exp. Sta. Bulletin B-285, "Fertilizing Wheat for Yield and Quality."

and nitrogen fertilizers or superphosphate following wniter peas. The legume residue also produces a valuable erosion control mulch.

Mineral fertilizers give best results when applied to legumes. Not all crops respcnd equally to fertilization; therefore, it is best to apply the fertilizer mainly to the crops giving best response. Where soils are acid, ground limestone is a desirable soil builder and may be necessary for certain crops. However, before lime and mineral fertilizers are applied the soil should be tested to determine if they are needed.

Strip Cropping

The effectiveness of strip cropping depends upon the production of an adequate cover of the right kind of vegetation to offer resistance to wind and water. Native grass strips interspersed between strips of cotton and occupying one-third of the land area reduced runoff water loss 38 percent during the past six years on deep sloping soil at Guthrie (Table XI). Not all the close-growing crops are as effective as grass; but various small grains, legumes, sorghums and other hay crops can often be used effectively.

METHODS OF CONSERVING LAND NOT SUITABLE FOR CULTIVATION

The shallow, sloping, highly erodible soils, as well as others unsuited for cultivation, are more stable and useful when put to permanent vegetation and used for livestock or woodland production. Grass and other permanent vegetation greatly reduces runoff water even from eroded shallow regrassed land (Table XII). The amount of runoff from such land was 33 percent less than that from cultivated terraced land, in tests at Guthrie. Native vegetation, however, reduced the runoff water loss 91 percent.

The following discussion summarizes research results applicable to land not suited to cultivation.

TABLE IX. Value of Various Amounts of Ammonium Nitrate in Increasing Effectiveness of Erosion-resisting Stubble Mulch Cultivation on the Wheatland Conservation Experiment Station, Cherokee, Oklahoma (1).

Pounds ammonium nitrate per acre(3)	Yield per acre(2)					
	Stubble mulched land				Plowed land	
	Barley		Wheat		Wheat	
	Grain (Bu.)	Straw (Tons)	Grain (Bu.)	Straw (Tons)	Grain (Bu.)	Straw (Tons)
None	19.4	0.75	18.3	1.22	17.4	1.18
12.5	20.3	0.64	19.7	1.37	19.1	1.12
25.0	21.9	0.78	21.3	1.38	18.9	1.34
37.5	22.1	0.82	21.1	1.51	19.4	1.41
50.0	21.9	0.75	20.1	1.44	18.0	1.40
75.0	25.0	0.94	22.5	1.63	19.8	1.44

1 This study is conducted under the leadership of Dr. H. F. Murphy, Head, Agronomy Department, Oklahoma A. & M. College.
2 Average of three years 1945-47 from duplicate treatments.
3 Applied as top dressing in March about the time the plants begin spring growth.

TABLE X. Effect of Fertilizer and Winter Legumes on the Growth of Wheat and the Development of a Better Cover on the Wheatland Conservation Experiment Station, Cherokee, Oklahoma (1).

Treatment(2)	Yield per acre(3)					
	1946		1947		Average	
	Straw (Tons)	Grain (Bu.)	Straw (Tons)	Grain (Bu.)	Straw (Tons)	Grain (Bu.)
None	1.04	20.9	1.23	17.9	1.13	19.4
Superphosphate	1.13	22.5	1.34	18.4	1.23	20.4
Superphosphate and ammonium nitrate	1.28	25.7	2.40	28.5	1.84	27.1
Ammonium nitrate (Fall)	1.10	19.8	1.52	19.6	1.31	19.7
Ammon. nitrate (Spring)	0.91	18.1	1.55	19.1	1.23	18.6
Wheat, wide row(4)	0.58	12.2	0.66	11.3	0.62	11.8
Wheat, wide row and superphosphate(4)	0.80	18.5	1.49	18.8	1.15	18.7
Wheat, following winter peas			1.52	26.4		
Wheat, following winter peas & superphosphate			2.27	28.8		

1 This study is conducted under the leadership of H. F. Murphy, Head, Agronomy Department, Oklahoma A. and M. College.

2 Superphosphate (20%) applied at the rate of 250 pounds per acre and ammonium nitrate at the rate of 100 pounds per acre. Wheat planted with a 10-inch semi-deep furrow disc drill. The data given are averages of triplicate treatments.

3 Yield per acre of Dixie Wonder Peas in 1947 was as follows: (a) no treatment—0.96 tons of hay and 14.5 bushels of seed; (b) with superphosphate —1.14 tons of hay and 17.6 bushels of seed.

4 Wheat rows 20 inches apart. Sweet clover was planted between rows, but it failed due to the weather.

TABLE XI. Effect of Native Grass Interspersed Between Strips of Cotton on the Conservation of Water at Guthrie, Oklahoma (1).

Kind of cover(2)	Percent runoff	Crop Yield (pounds per acre)	
		cotton Seed	Grass
Strips of native grass and cotton	9.3	487	3040
All cotton	15.1	471	

1 Average of six years results, 1942-47.

1 Grass, interspersed between each 22 rows of cotton, occupied about one-third of the area. All strips and cultivation are located and conducted on the contour

TABLE XII. Amount of Runoff Water from Different Kinds of Plant Cover at Guthrie, Oklahoma (1).

	Average runoff(2) (percent)
Cultivated terraced land	19.0
Eroded regrassed land	12.8
Native grass and woodland	1.8

1 Located on rolling, mainly shallow land.
2 Average of six years (1942-47) on eroded regrassed areas and eight years (1940-47) for other areas. Average total annual precipitation, 31.28 inches. This is 1.03 inches below that compiled by the Weather Bureau in Guthrie, since 1898.

Revegetation of Eroded Land

Many additional cattle could be supplied with pasturage if the millions of acres of idle and eroded land were revegetated. Grass re-establishes itself slowly under natural conditions on eroded land, but the process can be greatly speeded up by working with nature. The kind of vegetation and method of establishment vary with soil and climatic conditions.

The major problems to be overcome in regrassing eroded land are low fertility, poor physical condition of the soil, low available moisture, and poor biological activity (3). If the low fertility is due to mineral deficiencies, the needed minerals must be supplied by adding limestone and commercial fertilizers to the soil. Nitrogen may be obtained by growing legumes or by applying commercial fertilizers. Legumes such as sweet clover, vetch, and others supply organic matter; and the organic matter provides food for the microscopic soil organisms which improve biological activity (10). Under native vegetation, there is considerable biological activity. This may be observed from the decay of residue (caused by bacteria) and from activity of insects and worms. Eroded, abandoned land has lost most of its organic matter. As a result, there is little or no biolgical life to start rebuilding fertility and improving the physical condition of the soil (8).

Method of Seeding

If the land to be revegetated is seriously gullied or sheet eroded, special treatment will be necessary to re-establish vegetation (3). In some areas it may be necessary to divert the runoff water from the original channels by installing low-cost contour furrows or ridges between gullies and above the sources of the gullies. Satisfactory results have been obtained at Guthrie by installing vegetative barriers of brush and crop residue, plowing down the gully bank, applying a light application of fertilizer and lime when needed, and introducing legumes (Figure 6). After the legumes are established, grasses may be introduced.

For the more humid areas, Bermuda in combination with clovers and other introduced grasses does quite well on most soils. One of the most common methods of establishing Bermuda grass is by planting the root sprigs (11). Some other grasses are also giving good results, and may be established if found desirable.

Under arid conditions, native grasses in general seem to be best adapted. There are several methods of establishing these grasses. Satisfactory results

Fig. 6. Gully Control.

These gully control studies are being conducted on the Red Plains Conservation Experiment Station. (A) A gully before the banks were sloped and prepared for vegetation. (B) The same gully after the banks had been sloped and prepared for constructing vegetative dams, planting legumes, and applying a seed-hay mulch of native grass. (C) The same gully two years after the establishment of sweet clover and other vegetation. The density of vegetation in the treated gullies was over three times greater than that in the untreated ones.

have been obtained by applying mulches of mature hay containing seed(3), or by planting in a dead stubble of sorgo (13).

Fertilization of Grass

The effect of fertilizers on growth of grass is being tested at Guthrie (Table XIII). The first three years' data indicate that fertilizer is needed for grass production on eroded soils in central Oklahoma before sufficient vegetation can be grown to control erosion. Certain kinds of fertilizers may also be profitable for native grass production even on virgin soils. Fertilization will assist in developing a mulch cover for erosion control.

Cultivation of Grass

The effect of row cultivation on seed and hay production of grass has been studied at the Guthrie station since 1939. The results are given in Table XIV. In general, the broadcast areas have produced the most hay and the row plantings the most seed. In fact, the 42-inch rows produced an average of two times more seed than the broadcast strips. The quality of the seed produced was also considerably higher. From these results, it appears that light row cultivation might be beneficial for grass seed production.

Pastures sometimes become sod bound and occasional light disking is beneficial. The yield of Bermuda grass hay was increased 22 percent, and that of native grass 6 percent, by disking the sod lightly every other year in March (Table XV).

Management After Revegetation

After grass has been established, intelligent management is needed to improve and conserve the stand. Fall and winter mowing of poor stands

TABLE XIII. Effect of Fertilizer on the Yield of Grass; Guthrie, Oklahoma.

Kind of fertilizer(1)	Pounds of fertilizer applied per acre	Pounds of Hay Per Acre(2)	
		Weeping Lovegrass on severely eroded soils(3)	Native grass on virgin soil(4)
4-12-4	200	705	2286
4-12-0	170	801	1758
0-12-4	136	616	2067
4-0-0	50	854	2236
0-12-0	120	431	1905
0-0-4	16	615	1832
Manure	4000	903	1630
Manure and 0-12-0	4000 120		
None	None	400	1920

1 Each kind of fertilizer was applied on the surface of the soil in the spring, in triplicate on small plots.
2 Average of three years (1945-47).
3 Weeping lovegrass seeded broadcast in July 1944.
4 This area was cleared of scrubby oak in 1934, and has been used for pasture or meadows.

develops a mulch, saves seed which otherwise would blow away, supplies organic matter, and affords protection to the young seedlings. Spring mowing for weed control has also been quite beneficial in maintaining a good stand. The ideal time for this mowing is when the weeds begin to bloom. Light to moderate grazing, depending upon moisture conditions, aids in increasing the stand on reclaimed eroded pastures. Adjustment of grazing periods to permit the grass to produce seed is also helpful in improving and maintaining a cover.

Removal of Woody Vegetation

In adition to idle, eroded and abandoned land, Oklahoma has a large acreage of mixed native grass and scrubby, woody vegetation (Figure 7). Much of this land is being only partially used. The grass is sparse and the timber is of little value except occasionally for posts or firewood. The use of such land for pasture can be improved, however, by removing the trees and brush.

Value of Brush Removal

The average yield of grass on fully cleared virgin land was five times that found on land 90 percent shaded (3). Success as a pasture after clearing depends upon the kind of treatment and management it receives.

TABLE XIV. Effect of Cultivation on Seed and Hay Production of Grass; Guthrie, Oklahoma.

Method of planting (1)	Switch (2)	Little bluestem 3	Side-oats grama (3)	Weeping lovegrass 4	Average
Hay Yield (pounds per acre)					
Broadcast	1706	2369	1543	4494	2528
21-in. rows	2570	2757	1270	3358	2489
42-in. rows	2161	2380	1059	3490	2273
Seed Yield (pounds per acre)					
Broadcast	16	25	23	50	29
21-in. rows	37	74	48	55	54
42-in. rows	32	94	43	76	61

1 All row plantings were cultivated twice with sweeps during the growing season.
2 Four, (3) Six, and (4) Eight-year averages respectively.

TABLE XV. Yield of Hay from Cultivated Grass (1).
(pounds of hay per acre)

	Bermuda grass	Native grass (2)
Untreated	833	1811
Disked (3)	1015	1928
Increase in yield	182	117

1 Average of seven years of results, 1941-47.
2 Mixture of little and big bluestem and Indian grass.
3 Disked lightly every other year in March.

Fig. 7. Pastures and Meadows Out of Brushland.
Development of pasture and meadow from brushy land is being studied at the Red Plains Conservation Experiment Station. (A) The original cover of blackjack and scrubby oak that blanketed the land. (B) After the trees and brush were removed the grass soon spread and within three years developed a good cover. The first year after clearing, this land produced about one-half of a ton of hay per acre, the second slightly more, and the third about a ton. (C) Beginning with the third or fourth season after clearing this land may be used for pasture. The cattle harvest grass and produce beef and the grass protects the soil. The productive capacity of these pastures and meadows was increased about five times by this type of development and management (3).

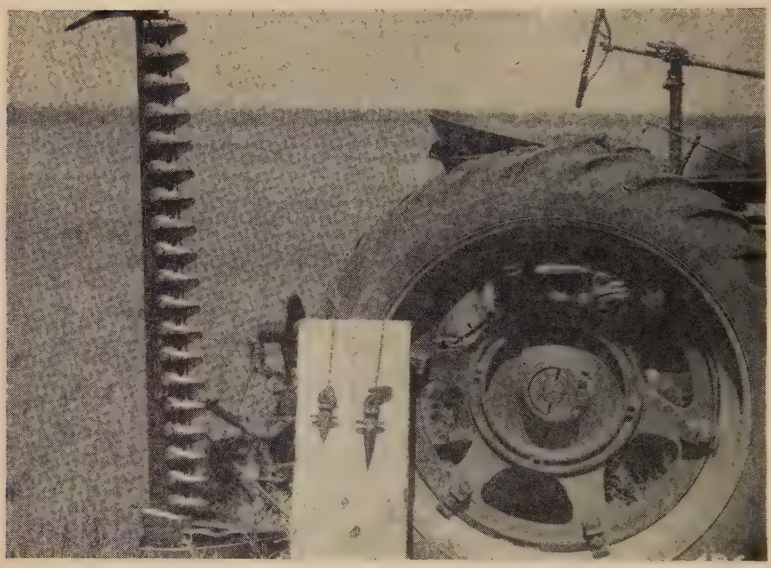

Fig. 8. Brush Mower Bar.
A standard five-foot bar equipped with stub guards and extra hold-down clips. Sickle is equipped with heavy sections. The exhibit on the board gives a comparison of stub and standard guards. This machine is capable of cutting brush stems up to 1½ inches in diameter during the growing season. Names and part numbers for brush bars or sickles of the different major companies will be furnished by writing: Project Supervisor, Red Plains Conservation Experiment Station, Guthrie, Oklahoma.

In tests at the Red Plains Station the native grass soon spread after the trees were removed, and within three years the stand of grass was equal to that of virgin meadow. Blackjack and white oak sprouts have been controlled by spring mowing. Those remaining after several years of mowing are largely running oak. Consistent annual mowing gradually reduces sprout growth, and after ten years the small quantity left offers little competition to the grass.

Full grass production will be obtained more rapidly, and erosion will be more completely controlled, if clearing is limited to areas having only light or medium brush cover. The original grass cover is more dense on gently sloping soil where the shade from woody vegetation is less. Therefore a complete grass cover is established more rapidly after brush is removed. There is also less likelihood of erosion starting between the time of clearing and the time the grass becomes well established.

In portions of the state, native pecans are intermingled with other trees and brush. The pecan production can be materially increased by thinning, removing competing vegetation, and proper management (**16**). When underbrush is removed from pecan groves, trees that seldom produced fruit, because of the competition for plant food, moisture, etc., yield good crops.

Methods of Removing Brush

The problem of controlling woody vegetation in both pastures and pecan groves is being attacked with both machines and chemicals.

Machines—Due to the possibilities of better land use created by removing scrubby trees and brush, several kinds of machines have been designed for cutting such vegetation (**1**). They include power mowing machines, tractor saws, small portable saws, chain saws, power brush beaters, bulldozers, tree dozers, heavy root plows, crushers, tree shears, and buck rakes. Brush mowers, saws, beaters, crushers and buck rakes have been tried on the station at Guthrie. They all gave satisfactory results when used on material within the limits for which each is best suited.

It appears unlikely that any one machine or clearing method can be developed to operate satisfactorily in all conditions and types of brush. A machine to handle brashy material such as sage or creosote brush must be quite different from one for tough, taller growing material like black-jack or persimmon.

The types of vegetation to be removed may be classified into three groups: brashy shrubs, tough shrubs, and trees.

Brashy shrubs, such as sage brush, creosote brush and sumac, can be readily cut with brush mowing machines (Figure 8). Such brush also breaks easily under the impact of a beater (Figure 9) or heavy crusher like a large

Fig. 9. Brush Beater.

This brush beater was constructed at the Red Plains Conservation Experiment Station. The machine is now equipped with steel gears and an 8-inch pipe drum for chain mountings. This type of machine is very effective for removing brashy shrubs similar to sage brush, or for sprout and weed control on stumpy or stony land where mowers cannot be used.

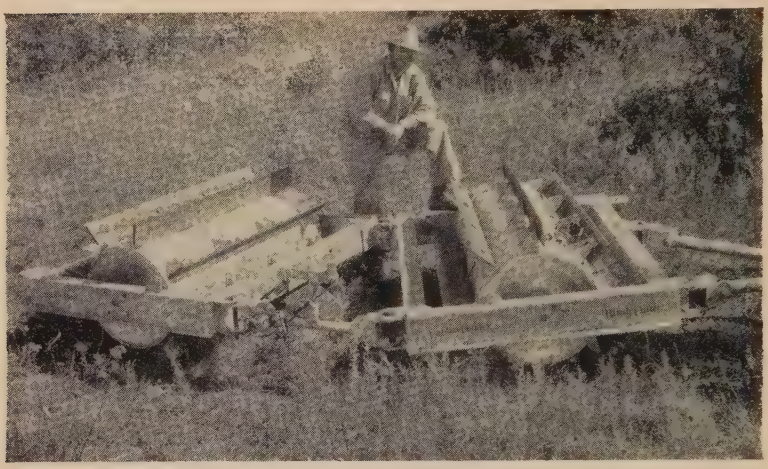

Fig. 10. Giant Stalk Cutter.
The medium size brush cutter weighs 4,200 pounds empty and approximately 6,000 pounds when filled with water. It is very effective for breaking down small trees or brush that have been killed with chemicals. It may also be satisfactory for breaking up some types of live brush and brashy shrubs.

stalk cutter. Sage brush was controlled to best advantage in western Oklahoma by cutting it in June (**14**).

Tough shrubs, such as thickets of plum, persimmon, blackjack oak, buck brush, or other woody plants with stem sizes up to 1½ inches, can be cut with a power brush mower or a heavy stalk-cutter type machine (Figure 10). Portable saws, either tractor mounted (Figure 11) or small (Figure 12), have also performed satisfactorily for cutting this kind of brush.

Trees ranging in trunk size from two inches or larger may be removed with saws or dozers on large crawler tractors. Small portable saws were most satisfactory on trees ranging in size from two to ten inches in diameter. Larger trees were cut, but with increasing difficulty. Much larger trees were cut with tractor-mounted saws, and they work as well as the portable saws on the smaller trees. Chain saws (Figure 13) operate best on large trees. They can be used on steep banks or in close places where other types of saws cannot be operated.

Brush buck rakes (Figure 14) have been used to eliminate many man-hours of labor for assembling the brush after cutting. When a tractor saw was followed with a buck rake and the brush assembled and pushed into piles, much time and labor was saved. Results to date indicate that the time required for land clearing with four men and a portable saw was between thirty and forty man-hours per acre. When a buck-rake, portable saw and three men were used, the time varied from twenty and thirty man-hours per acre. But a tractor saw and buck rake combination reduced the time for clearing to between five and ten man-hours per acre. Perhaps the most rapid land-clearing machines available are bulldozers. They are being widely used by contractors.

Chemicals—Chemicals for brush control (Figure 15) have been studied at various locations in Oklahoma during the past three years by the Okla-

Fig. 11. Tractor Power Saw.

The saw blade is driven through bevel gears in the housing above the blade. Power is taken from the belt pulley of the tractor. Height of cut is manually controlled. For cutting brush and small trees, this saw can be operated while the tractor is in motion. Larger trees are cut by stopping the tractor and swinging the blade into the trunk. The high dozer bar or push frame prevents the tree from falling on the tractor.

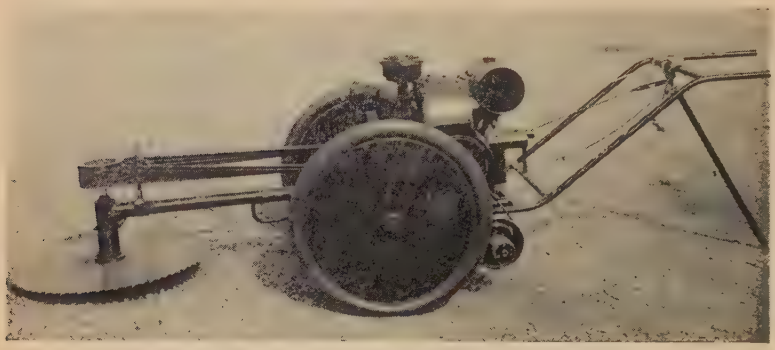

Fig. 12. Small Portable Power Saw.

This machine is self-propelled and the saw is driven by four v-belts. It is very maneuverable and most efficient on brush and trees ranging up to ten inches in diameter. Larger trees can be felled, but with slightly more difficulty. Standard cordwood saw blades are used on this machine.

Fig. 13. Chain Saw.

There are two types of portable chain saws on the market. These saws are best adapted for large trees. They can be used for land clearing on very rough terrain or creek banks where tractor or other power saws cannot be operated.

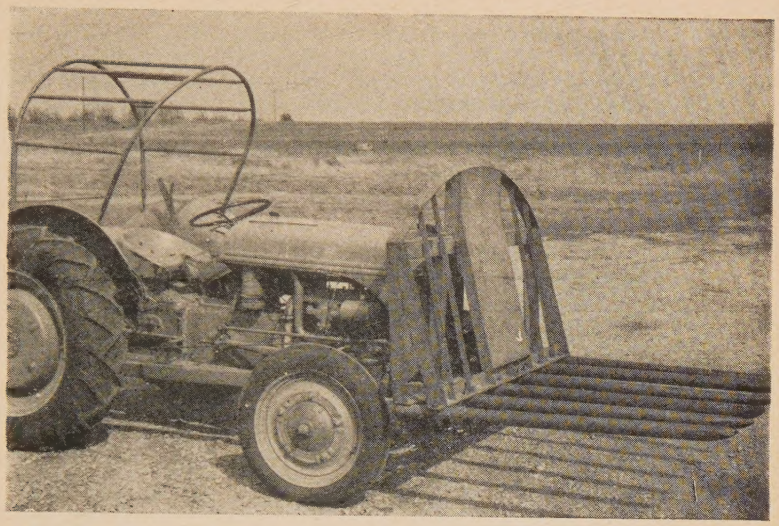

Fig. 14. Small Buck Rake.

This small power-lift buck rake is 5 feet wide and the teeth are 4.5 feet long. This size rake is very desirable for picking up brush or trees and pushing them out of the way when sawing with tractor saws. The small size is a distinct advantage for maneuvering in and out of close places. Details for building this rake and a larger buck rake (3) 12 feet wide will be furnished by writing: Project Supervisor, Red Plains Conservation Experiment Station, Guthrie, Oklahoma.

homa Agricultural Experiment Station. One of these chemicals is dichlorophenoxyacetic acid, a selective material commonly called 2,4-D. There are many commercial formulations containing this ingredient. Another material known as Ammate (ammonium sulfamate) is not selective—that is, it kills all plants to which it is applied. Neither 2,4-D nor Ammate is poisonous to man, animal, or the soil. Directions for the use of the various products are given on the containers. The best time to apply them appears to be in the spring when the plants are in a green, growing condition.

Some types of brush are resistant to 2,4-D. On types affected by 2,4-D, a number of conditions influence the percentage of kill (7). Water solutions did not give satisfactory kills on brush over three inches in diameter or ranging above 6 feet in height. Plants 80 to 95 percent affected by one application of 2,4-D were sumac, sand plum, black and honey locust, persimmon and sassafras. Those 50 to 75 percent affected were blackjack, post and dwarf chinquapin oaks, and willow. American and winged elms, mesquite, hackberry, hickory, bois d'arc and red cedar were not affected by 2,4-D sprays in the 1946 tests. All of these plants were readily affected by Ammate sprays. However, on some of the aras treated, a second or third application was necessary to completely kill the brush. Ammate used at the strength required to control brush greatly affected the native grass.

Mixtures of chemicals were tried in 1947 in an effort to avoid injury to the grass and also to allow the 2,4-D a better opportunity to attack the woody plants. The mixtures tested were: (a) 2,4-D and deisel oil, and (b) 2,4-D and Ammate in water (7). It appears from the 1947 results that either combination was more effective on trees than was either chemical used alone. It also appears that these mixtures may reduce the cost of treatment.

After the brush has been deadened it remains standing for several years if not broken or crushed down. A heavy stalk-cutter type machine (Figure 10)

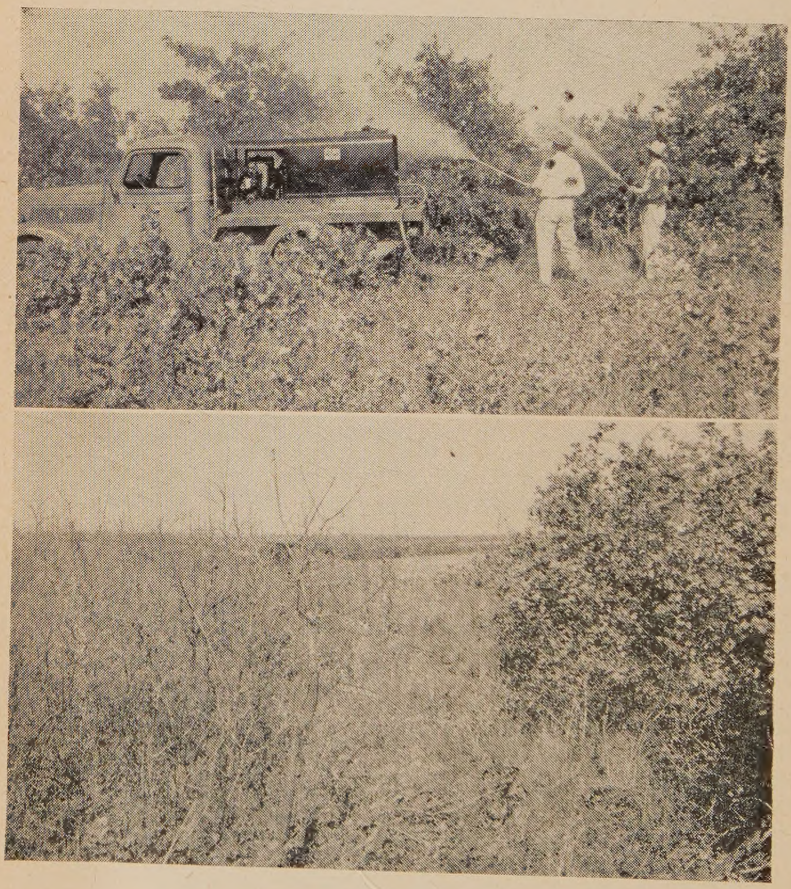

Fig. 15. Chemicals for Brush Control.

More and more attention is being given to the control of undesirable plants on ranges, pastures and pecan groves. Above, blackjack brush is being sprayed with chemicals. Below, the brush on the left was treated with Ammate, that on the right was untreated.

has been used for this purpose the second and third years after applying the chemicals. It crushes the dead material and forms a mulch on the surface of the soil which conserves moisture and improves fertility.

Scattered trees may be killed by injecting chemicals into axe incisions which completely circle the tree near the ground. Ammate applied in this way has given good kills on small trees. On larger trees, sodium arsenite (one pound per gallon of water) has been the only material used that gave satisfactory results. **Arsenite is very poisonous and must be handled carefully.** Neither of these two products was effective when applied on stumps.

Beef Production

The establishment and improvement of pastures on unused land is practical for the average landowner or occupier. Pastures on idle, eroded or scrubby woodland may be maintained by keeping out fires, conservative use, and eliminating undesirable sprouts and weeds. These practices will assist in developing a mulch cover for erosion and flood control. Through proper management, much of the eroded and unused land in Oklahoma could be converted into useful pastures and meadows; and, if grazed conservatively, such land will give satisfactory returns.

Production of hay and beef was much higher on the virgin land from which brush had been removed than it was on eroded land that had been regrassed (Table XVI). The amount of beef produced during summer grazing with yearling steers has averaged 39 pounds per acre during the past four years on previously eroded land at the Guthrie station. On cleared virgin land it has averaged 63 pounds per acre. But beef gains on regrassed eroded land can be increased by fertilization. When phosphorus and nitrogen fertilizers were applied to regrassed land in the spring of 1947, beef production the following summer was increased about two and one-third times.

This system of brush removal, regrassing, fertilizing, and management of formerly unused land paves the way to permanent and stable pastures and meadows. Sound development and use of such land controls erosion and provides an opportunity for greater production. Thus, soil conservation and balanced farming are being accompanied logically and profitably by sound development of the livestock industry.

TABLE XVI. Use of Shallow Soil For Livestock Production; Guthrie, Oklahoma.

Kind of soil	Beef Produced per acre (pounds)		Average yield of hay per acre(1)
	1947	Average(1)	(tons)
Cleared virgin	65	63	1.00
Regrassed eroded	36	39	.50
Regrassed, fertilized(2)	86		

1 Four-year average 1944-47.

2 An application of 300 pounds of 20 percent superphosphate and the equivalent of 100 pounds of ammonium nitrate per acre was applied in April, 1947.

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